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RIVER TERRACES AND REVERSED DRAINAGE.

THE south-central portion of New York state, or the plateau region, is furrowed by narrow north-south valleys. A study of a map made by combining the United States Geological Survey topographic sheets, representing the quadrangles lying between the Mohawk and the Susquehanna (Chenango-Chemung) valleys, draws attention to its peculiar drainage features and physiographic development. The presumption of reversed drainage, suggested in many instances by the map, is often borne out by a study of actual conditions in the field.

It is not the purpose of the present paper to consider the major features of a region extremely interesting and complex in its physiographic history, nor to correlate the analogous surface characters to be found in the numerous interrelated valleys. A future paper may consider these greater problems, and the presentation of many data gathered in field work extending over a large portion of the whole area.

These valleys of the dissected plateau region grow more trenchant in character and more rugged in their topography in passing from north to south. They all share in one common feature: that the preglacial floors are deeply covered with drift. The actual depth of filling may vary and fluctuate, but is from several hundred to something less than one hundred feet deep. Well borings of less than one hundred feet do not usually reach bed rock (Fig. 1). The locality herein considered is situated in Tioga county, N. Y., along the course of the Catatonk River. This stream heads in a flat, swampy divide on the valley drift, one mile east of the town of Van Etten, and, after flowing about nine miles in an easterly direction to North Candor, turns abruptly to the south. It maintains a practically southern direction for twelve miles, and, after uniting with Owego Creek, empties into the Susquehanna (Chenango) near the city of Owego.

The main stream follows a wandering course through the gravel-filled valley, never exposing rock *in situ*, except in one

place, where by swinging it has undercut the valley wall. The surface of the valley presents the aspect of a flat, level plain of drift-filling from valley wall to valley wall, in which the Catatonk River has excavated a shallow trench (Fig. 2). For the most part this stratified drift in the valley bottom is composed of rounded pebbles and coarse gravel, with intercalated beds of sand and at some depth beds of clay.

In the fall and spring the Catatonk River is rapidly converted

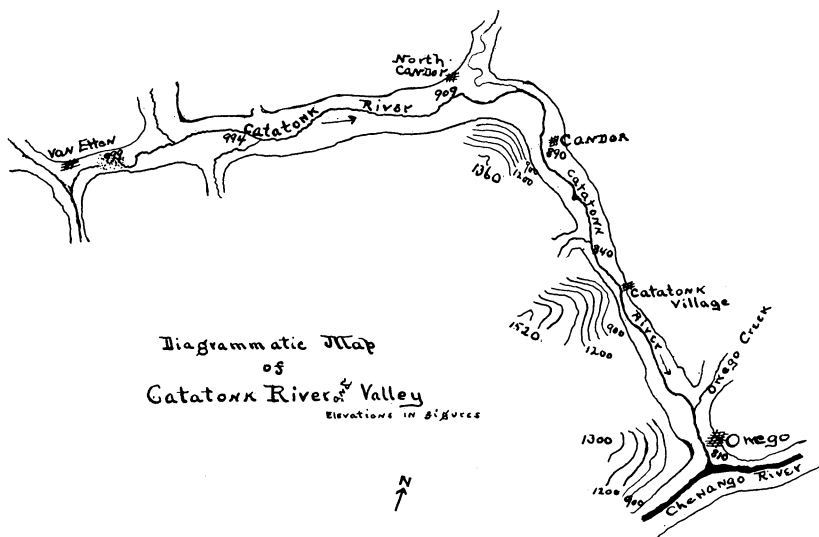


FIG. 1.

into a flooded condition by the rains and melting snows descending rapidly from the high valley walls in a diversity of small streams. Some of these latter are more or less persistent streams, having a drainage heading back onto the plateau, or inter-valley areas. They carry considerable detritus from the upland, and plunge with a cascading rush down the escarpment of the main valley to the master stream. Much of their sediment is often deposited in alluvial fans, or cones, at the base of the valley wall, where the equilibrium between volume and load is abruptly broken. The residue, under a new adjustment, is strewn over the valley flood-plain or delivered to the main stream. The main stream is, therefore, for a part of the year essentially an aggrad-

ing rather than a degrading stream. The rest of the year the volume is extremely small, and the work accomplished proportionally slight. Such being the case the main stream, as at present constituted, is doing, and apparently has done, little work of vertical erosion.

In different parts of the valley, however, are remnants of well-developed terraces of destructional origin, which are out of all

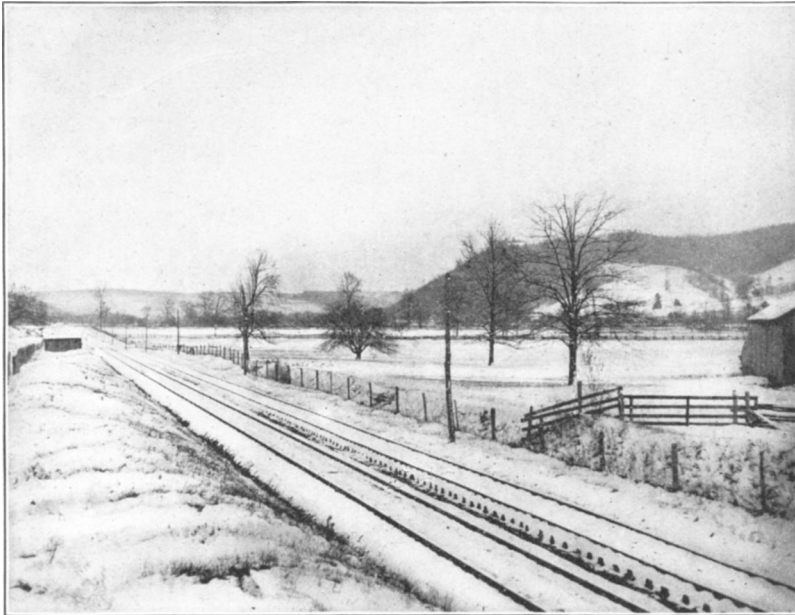


FIG. 2.—Drift-covered floor of Catatonk Valley, N. Y.

proportion relative to present drainage conditions. The terraces are not continuous for any great distance, and often are entirely wanting on both sides of the valley. At some time during the preglacial period, and therefore previous to the deposition of drift, the valley was probably drained by two streams; one flowing to the north and one to the south from a common divide. In the lower half of the valley, as one proceeds from North Candor to Catatonk village, the valley grows gradually narrower, and a projection of the valley slopes intersect at a point much nearer the surface of the drift than toward the head of the valley,

although one is proceeding toward the mouth of the present stream, and where the greater maturity should be expected. Near the village of Catatonk the valley walls also reach their highest elevation—somewhat over 1,500 feet. North and south from this point the inclosing hills slope gradually away in both directions to an elevation approximating 1,300 feet. That is, the upland elevation opposite North Candor is about 1,360 feet, and opposite the present mouth of the stream, near Owego, the elevation is 1,280 feet; while between these two points the elevation exceeds 1,520 feet. If the surface contour of the upland represents the old preglacial topography, then the height of land must represent an original divide, over which the present stream is now flowing in a reversed course to the south.

The slope of the buried rock floor was obtainable only at two points, but shows that between Catatonk village and North Candor it is toward the north. The rock bottom, or preglacial floor, of the valley is thus deeply buried, and its grade and development do not necessarily coincide with that developed by the present stream over the surface of the drift filling.

In studying the probable history of the valley, relative to other adjacent valleys, and their bearing on the physiographic development of the region as a whole, the terraces furnished an additional suggestion as to a change that the drainage may have undergone. Professor W. M. Davis¹ has brought out many pertinent facts as to the origin, pattern, and preservation of river terraces. Many ideas there expressed were applied to the study of the Catatonk River terraces. It has been shown by Davis that the carving of destructional river terraces does not necessarily imply a greater power in a stream during past time and that the present stream is one of diminished volume. On the contrary, he points out that such features may be produced by stream-swinging and the migration of its meanders down stream, now on one side of the valley and now on the other, the volume remaining constant. Each return of the meander at a lower level would mark a terrace plain. A stream, unthwarted

¹ DAVIS, "River Terraces in New England," *Bull. Mus. Comp. Zool.*, Vol. XXXVIII (October, 1902).

in its work and excavating in homogeneous drift, might also on a return vibration undercut one or more terraces left by a previous shifting of its meanders. This would leave its vertical downcutting, or erosion, expressed in a high escarpment, which would represent the sum of later terrace scarps combined into a single scarp coincident with one of an earlier terrace.

Davis also calls attention to the fact that the preservation of a series of terraces is due to the dominant influence and controlling power of buried ledges. These latter have the character of an upland spur projecting transversely out into the valley. A degrading stream in alluvial deposits, finding itself superimposed upon a transverse rock spur, would tend to migrate farther toward the axis of the valley, and thus slip by the obstruction, provided it was not so far incised laterally as to be held fast by the spur. The succeeding meanders, degrading having gone on, would return at a lower level and impinge upon the intercepting ledge still nearer the axis of the valley at each successive swing. On the other hand, a down-sweeping meander having encountered the buried ledge, and having a curvature above it well developed through deep lateral cutting, might be held fast by the projecting rock spur and unable to slip by. Succeeding meanders having advanced down stream, and their curvature above the ledge having been highly compressed, they would undercut and scour out former terracing by the enforced increase in the radius of its lateral cutting. This might continue until the meander became so compressed that it would eventually destroy itself by a cut-off, and allow the stream to pass the ledge by straightening its course. The presence of such spurs and buried ledges would defend and preserve on its immediate lee, or down-valley side, any terracing cut at an earlier period in the drift covering above it. Thus a salient of terraces would be preserved above the rock defended cusps.

The Catatonk River terraces do not lend themselves to such interpretations, either as being the work of a stream of constant volume, or their preservation being due to the intervention of a protecting spur (Fig. 3).

If we agree that the radius of a meander curve is limited and

proportional to a given stream flow, and when not interfered with will gradually bring itself to maturity, then the down-sweeping of an unobstructed meander must eventually result in its collapse and self-destruction through the medium of a cut-off. The present Catatonk River has obsolete meanders, now represented by more or less filled in cut-offs, or miniature oxbow lakes, that



FIG. 3.—Terraces along Catatonk River, N. Y.

seem to gauge the limit of its radius in meander development. The full extent of its present mature meanders and the shifting of the meander belt is much less than the opportunity offered by the flat bottom plain extending across the valley.

To whatever state of maturity the valley development had attained preglacially, it was directly modified by the advent of the glacial epoch. The old valley floor and its grade must have been somewhat affected by the southward movement and erosion of the first ice advance, and a probable lowering of the preglacial divide. Upon a subsequent retreat of the ice it was

aggraded by the fluvio-glacial débris. Later, the extra-morainic wash from the highly developed "kettle" morain, or the terminal morain of the second ice advance, lying only a few miles to the north, must have overwhelmed these intrenched valleys with floods of drift, under which their floors now lie deeply buried.

The proximity of the halted ice-front, and the immense load of detritus carried on, in, and beneath the ice, must have aggraded with tremendous rapidity the narrow valleys adjacent to it. The volume of drainage, fed by subglacial streams, by the general melting of the ice-front, by drainage from the land just released from the ice, and by the presumed greater precipitation of the glacial epoch, must have filled these valleys with streams of great volume, even after the continuity of the ice-sheet was broken by the melting upon hilltops and divides. Under such conditions it is not credible that the stream can be classed as one of either constant volume or load.

Drainage to the north was held in restraint by the blockage of the ice-front itself, and such conditions must have existed in north-sloping valleys as to transform them into temporarily ponded basins. The north-sloping valleys having become regions of more or less static water, the lower part (preglacially) of these valleys would be the points of greatest deposition. Helped in great measure by such aggrading and filling, the northward streams were compelled to flow over their former divides and adopt a southward outlet.

With the steady retreat of the ice two conditions of paramount importance must have been imposed upon the drainage: diminution in load, and a gradually diminishing volume. Both of these factors are of importance in the solution of these terraces, for a differential of either would affect the activity and scope of stream excavation. In the case in hand bold spurs do project into the valley flanked by terrace plains, but the interesting fact in regard to them is that the terraces appear on the *north* side, or up-valley, of the projecting spur, while the drainage flows to the south. It has been shown by Davis, both in text and by a variety of progressive illustrations, that terraces related to protecting spurs are removed by the stream on the up-

valley side, and only by the rarest chance are destroyed in the curve adjacent to the down-valley side. That these terraces are preserved with a south-flowing stream, upon the north side, or up-valley, would seem to indicate that there had been a north-flowing stream since the drift deposition of glacial time.

It is evident that there has been a reversal of drainage since the initial development of the valley in preglacial time, but the position of the terraces would indicate that they were due to the postglacial meandering of a north-flowing stream, and that their preservation was due to the superimposition of the stream on the projecting rock spur. That there has been a second reversal since the inception of the close of the glacial epoch, subsequent to the drift deposition, does not seem rational. Though a postglacial uplift may have taken place, it does not appear from any analogous development in the region that it was of a sufficiently revolutionary character to bring about such a change.

As both the highest level terrace plain and the lowest part of the valley bottom are a homogeneous, assorted, and glacio-fluviatile drift, from one end of the valley to the other, the possibility that the terraces are remnants of a flood plain developed previously to the glacial epoch is not great. If they are the result of lateral swinging by a south-flowing stream, of constant volume, they should have been undercut and concentrated, or else distinctly modified by its successive meanders.

It is not essential to the solution to discuss in detail the various causes of reversed drainage, whether by headwater piracy, ice erosion, aggrading, or land tilting, nor the evidences of the same as expressed in the Catatonk Valley; but, so far as either the negative or the positive evidence of the terraces suggests anything, it tends to strengthen the belief that neither slope, load, nor volume has remained constant since the drift-filling and aggrading took place.

There is some additional evidence in the fact that the terrace fronts have a vastly greater arc of curvature than is developed by the swing of the present stream.

It seems likely from the fragmentary evidences that the valley was occupied, for a time subsequent to the withdrawal of the

ice, by a larger and more powerful south-flowing stream which had the potential of terrace-carving, either by diminished load or diminution of volume—possibly both. The accident of position and preservation is entirely independent of the presence of projecting spurs.

It is believed that an application of Davis's theories of terrace origin, pattern, and preservation, and their adaptation or non-adaptation to a given problem, may often afford suggestions as to the history of valley development by streams.

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